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DIETARY SUPPLEMENTS FOR CONSIDERATION IN ELITE FEMALE FOOTBALLERS

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ABSTRACT

The physical demands of professional female football have intensified in recent years. Supplements are only advised in addition to a healthy, balanced diet, but may warrant a greater prevalence in the professional game to support well-being, recovery, and performance. Supplements used by players should be safe, legal, and scientifically proven to be effective. An individual approach should be taken to using supplements dependant on the needs and goals of the player. Female players should aim to improve the frequency of protein intake throughout the day, whilst tailoring doses to individual body mass. Vitamin D supplementation is vital throughout the winter months in countries with limited sun exposure, however doses should be administered based on individual blood test results. Iron is likely to be important to the well-being of female athletes throughout the season, in particular during the menses. Omega-3 and collagen may be of greater benefit to female than male athletes during recovery from soft tissue injury, whilst probiotics and creatine are beneficial throughout the season for reducing risk of illness and optimising recovery, respectively. Ergogenic supplements for football include beta-alanine, nitrate and caffeine. Caution should be taken with caffeine use due to the varying tolerance of difference athletes and sleep impairments that can follow.

Keywords: Team Sport, Recovery, Performance, Nutrition, Gender

INTRODUCTION

The dietary supplement market consists of an unimaginable variety of products which are easily available to the general population. Dietary supplements are marketed and perceived to be vital in achieving optimal health and athletic performance. This perception creates interest amongst athletes and coaches who seek to gain an edge to performance, optimise recovery or improve health and well-being.

The IOC Consensus statement (Maughan, 2018), defines a supplement as ‘a food, food component, nutrient, or non-food compound that is purposefully ingested in addition to the habitually-consumed diet with the aim of achieving a specific health and/or performance benefit.’ This statement promotes that the foundations of an athlete’s diet should be based on a varied, whole-food intake, where supplements should only be used in addition to a healthy balanced diet and not as a replacement for food.

However, in certain circumstances where whole-food intake cannot achieve the desired outcomes, supplements may be useful. These include:

- for correcting nutrient deficiencies or achieving optimal nutrient intake e.g. in female athletes with higher iron requirements or vegan athletes
- for convenience when travelling e.g. poor availability of high-quality food
- for athletes experiencing a loss of appetite e.g. pre- or post-competition
- for a direct performance benefit e.g. a batch-tested, evidence-based ergogenic aid

The flow chart shown in figure 1 (Close et al., 2016) is a useful tool for determining whether use of a supplement may or may not be necessary.

Garthe and Maughan (2018) concluded that supplement use amongst athletes increases with level of performance, whilst the types of supplements used, varies between males and females. In professional football it appears that approximately 57% of professional male players use dietary supplements as demonstrated by research gathered from the 2002 and 2006 FIFA World Cup tournament (Tscholl et al., 2008). There are currently no studies determining the prevalence of supplement use in elite female footballers.

Over the last decade, the level of performance and professionalism within female football has progressed dramatically (FIFA physical analysis report). Many top tier women's teams, such as those in the Women's Super League (WSL), now have full-time contracts and the physical demands of the game have increased (FIFA., 2019). Although investment from commercial partners has grown within women's football over the last 4 years (The FA, 2020), there remains a lack of integration and funding from professional men's clubs that have a women's football section (Wrack, 2020; Valenti, 2019). Financial limitations create additional pressures and challenges for female players, which can in turn, hinder recovery and performance; players will often travel to weekly fixtures by coach rather than plane thus extending travel time, disrupting sleep routines, and limiting recovery. Budgetary restrictions can also limit food provision at the training venues of female players, which may result in suboptimal nutrient intake. When there is restricted opportunity to engage in optimal nutrition behaviours, the use of dietary supplements advised by a qualified Nutritionist may be a convenient and cost-effective option to ensure that the recovery, health and performance of female footballers is not sacrificed.

Asides from lifestyle variations, there is growing evidence that the physiological (Pitchers & Elliot-Sale, 2019), endocrine (Park et al., 2009) and anatomical (Pitchers & Elliot-Sale, 2019) differences between men and women, could put female athletes at greater risk of certain injuries, such as anterior-cruciate ligament (ACL) injury. These are of highest prevalence in sports involving jumping or multi-directional movements, such as football (Pitchers & Elliot-Sale, 2019). Therefore, supplements known to be beneficial for ligament rehabilitation or attenuation of muscle atrophy during injury in female athletes, such as collagen or omega-3 fish oils, could benefit the return to play in female footballers.

Although there are plenty of studies to support the efficacy of supplement use in football, there is limited research specific to the female population. The aim of the following review is to outline dietary supplements that demonstrate growing evidence to support the demands and promote the health, recovery and performance of elite female footballers.

MACRONUTRIENT SUPPLEMENTS

Low energy availability (LEA) is frequently observed among female athletes and is often related to the management of optimal body mass or physique. Interview data from professional female football players highlights players avoiding carbohydrate after intense training sessions due to body composition testing concerns (Culvin 2019). LEA also occurs when there are reduced opportunities to consume food around training and match play. Female football players typically have other commitments and busy schedules outside of their day-to-day training, meaning the opportunities to consume food may be limited in some cases. Indeed, in-season observations of professional female players demonstrate that 23-33% of players had LEA, and up to 19.3% of elite players report menstrual dysfunction, a common symptom of LEA (Moss et al., 2020). In female players, the menstrual cycle results in large fluctuations in hormones (e.g. estrogen & progesterone) which in turn alters physiological function. Interview data from elite female rugby players highlights that 67% of athletes studied considered menstrual cycle related symptoms to negatively impact their performance in training/competition (Findlay et al., 2020). When taken together this highlights the importance of optimal macronutrient intake not only for minimising the risk of LEA, but also providing a convenient way to assist with daily nutrition goals, while maximising recovery and adaptation between training sessions and supporting performance across the menstrual cycle. As such, protein and carbohydrate (CHO) supplementation should be considered.

Generally, a total daily protein intake of 1.-2.0g/kg is suggested for football players to allow for chronic amplification of the muscle protein synthetic (MPS) response to training (Oliveira et al., 2017). Studies have demonstrated that female football players typically consume adequate total daily protein in accordance with these guidelines (Clark et al., 2003; Martin et al., 2006). However, it is apparent that the distribution of protein throughout the day may have more influence on the modulation of MPS in comparison to the total daily protein intake (Areta et al., 2013). To the authors knowledge there is currently no data specific to female football players, however previous data from professional male (Anderson et al., 2017) and elite youth (Naughton et al., 2016) football players highlight a skewed intake of protein throughout the day, and suboptimal intakes particularly with evening snacks. Given the importance of the daily distribution of protein, 20-40g (~0.3g/kg) high quality protein split evenly through the day every 3-4 hours is advised to maximally stimulate MPS (Areta et al., 2013). Protein should also be consumed at the appropriate times around training in order to maximise recovery, and as such, 0.3-0.4g/kg in the first 2 hours following a training session or match is suggested. During recovery, supplementing with whey protein is considered the optimal choice due to its higher leucine content (1-3g) and rapid digestion (Phillips, 2016). The addition of a leucine rich protein source to the recovery meal/snack after training or match play together with carbohydrate intake (0.8g/kg) also assists with accelerating muscle glycogen resynthesis. Previous findings from professional male players (Anderson et al., 2017) indicate that protein intake in evening snacks prior to sleep has been sub-optimal (0.1g/kg), however there is increasing evidence to suggest that consuming 30-60g of casein protein at this time enhances MPS overnight (Trommelen & Van Loon, 2016).

CHO intake should be periodised based on training and match intensities with current recommendations suggesting between 3-10g/kg daily (see Oliveira et al., 2017 for further detail). Following matches and during training sessions, CHO gels, drinks and bars can be used for convenience.

OMEGA-3

Omega-3 fatty acids are consumed in the diet through oily fish, such as salmon and mackerel, or by supplementation with fish oils. Omega-3 supplementation has become popular amongst athletes due the potential to optimise muscle recovery, injury rehabilitation and cognitive function (Rawson et al., 2018). The two main components of omega-3 are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). EPA and DHA are thought to protect the integrity of cells and offer anti-inflammatory properties which can attenuate the severity of exercise induced muscle damage (EIMD) (Calder, 2015).

The multi-directional movement patterns of football players are known to cause significant muscle fibre damage (Philpott et al., 2018). Although findings have been equivocal, there is growing evidence to suggest that chronic omega-3 supplementation may improve muscle recovery (Jouris et al., 2011; Philpott et al., 2014; Black et al., 2018) and subsequent sporting performance (Black et al., 2018) following EIMD. Unfortunately, there are no studies that have independently investigated the effect of omega-3 supplementation on muscle damage in female athletes. However, in trained male football and rugby players, 5-8 weeks of omega-3 supplementation with 2-3g/day has shown to reduce muscle damage, soreness (Philpott et al., 2014) and fatigue (Black et al., 2018) following EIMD. Only within a real-world training environment did these findings translate into performance improvements (Black et al., 2018).

Although omega-3 supplementation appears beneficial to team sport athletes such as footballers, it is unknown whether the findings would translate to female athletes, specifically.
Interestingly, there is evidence to suggest that the neuroprotective effects of estradiol may attenuate the extent of EIMD and repair response, in healthy, active females who are normally menstruating compared to females using oral-contraceptives and healthy, active male participants (Minahan et al., 2015). Although there are contradicting findings within this area (Sewright et al., 2008), Minahan et al. (2015) accounted for confounding variables, such as peak torque strength and oral contraceptive use, which has not been considered in all other studies. If further research can support the notion that reduced concentrations of oestrogen result in exacerbation of EIMD and prolonged recovery time, then omega-3 supplementation could pose greater benefit to the recovery of female footballers using oral-contraceptives compared to those that do not.
Omega-3 supplementation is also thought to improve neurocognitive function in females; 4 weeks of DHA-rich omega-3 (3.5g/day) improved reaction time efficiency in female football players (Guzmán et al., 2011). These findings show that different compositions of omega-3 supplements may enhance physical adaptation and neuromotor function in female soccer players.

During immobilisation injury, muscle disuse leads to reduced rates of muscle protein synthesis (MyoPS) and anabolic sensitivity (Mcglory et al., 2019). Chronic omega-3 (3g/day) supplementation has shown to improve the anabolic sensitivity of muscle following feeding in healthy young men and women (Smith et al., 2011). Mcglory et al., (2019) demonstrated that 5g/day of omega-3 could improve recovery from limb immobilisation in females, by elevating rates of MyoPS and attenuating muscle atrophy during the limb immobilisation phase. Maintenance of muscle mass not only enables a faster return to play, but can also reduce the risk of considerable fat mass gains as resting metabolic rate is better preserved. Aside from soft tissue injuries, contact sports naturally increase the risk of mTBI in athletes. There is evidence that supplementation with DHA prior to, or in the early stages of mTBI can offer a neuroprotective effect, therefore attenuating the deleterious brain function associated with head trauma (Rawson et al., 2018).

VITAMIN D

Vitamin D and its metabolites are a group of secosteroid hormones which are primarily synthesised in the skin. Indeed, the main source of vitamin D (80-90%) comes from sunlight exposure, with only the remaining 10-20% being provided through diet (Owens et al., 2018). As such, many athletes including professional footballers present with vitamin D deficiency particularly during the winter months (Morton et al., 2012). Vitamin D has previously been shown to have important roles in immune function (He et al., 2013), muscle repair (Owens et al., 2015), and bone health (Lappe et al., 2008). Therefore, it is important that football players are tested periodically throughout the season to identify any deficient players and help minimise illness and injury risk.

Of particular relevance to the female player, vitamin D deficiency (25(OH)D <20ng/mL) has been linked to increases in inflammatory markers such as IL-6 in female populations during the pre-menstrual phase of their cycles. During this phase, PMS symptoms such as headaches, nausea and cramps typically occur due to changes in oestrogen and progesterone. These inflammatory markers have been shown to be reduced following a period of supplementation with vitamin D3 (Heidari et al., 2019). Furthermore, previous research in female Navy recruits has assessed the incidence of stress fracture injuries over 8-week training periods when supplemented with either 2000mg of calcium and 800IU vitamin D per day or a placebo (Lappe et al., 2008). Data demonstrated that out of the 3700 recruits, 309 were diagnosed with a stress fracture, with a 21% lower incidence in the supplemented group compared to placebo. This highlights the importance of calcium and vitamin D intakes and the need for supplementation to minimise injury risk if deficiencies are present. When looking specifically at female football players, the limited data available suggests that vitamin D intakes are suboptimal throughout the football season (Clark et al., 2003; Gibson et al., 2011). As such, there is a greater risk of stress fracture type injuries and illness, particularly when combined with the effects of LEA.

In applied practice, 25[OH]D is the best marker to identify the vitamin D status of players. Table 1 below outlines the guidelines for the classification of vitamin D status. When a deficiency is observed, or during the winter months where sun exposure is not possible, a supplement in the range of 1000-2000IU per day is suggested until the deficiency is corrected.

IRON

Iron is a fundamental mineral used by the body for multiple processes such as oxygen transport and energy production. Research suggests that the minimum blood markers needed to assess iron status are; ferritin, haemoglobin concentration and transferrin saturation (Sim et al., 2019). Peeling et al. (2007) have proposed the following categories to define the varying levels of iron deficiency (ID) in athletes.

- Stage 1 – iron deficiency (ID): ferritin < 35 μg/L, Hb > 115 g/L, transferrin saturation > 16%
- Stage 2 – iron-deficient non-anaemia (IDNA): ferritin < 20 μg/L, Hb > 115 g/L, transferrin saturation < 16%
- Stage 3 – iron-deficient anaemia (IDA): ferritin < 12 μg/L, Hb < 115 g/L, transferrin saturation < 16%

The prevalence of ID in female athletes is thought to be between 15-50% (Sim et al., 2019). Landahl et al., (2005) found that 57% of international level female football players had ID with 29% suffering from iron-deficient anaemia (IDA). Female football players are at increased risk of ID as a result of blood loss during menses. A female footballer with reduced iron stores can suffer from lethargy, fatigue and low mood which are likely to have an impact on training, sleep and match performances.

Iron cannot be endogenously synthesised; therefore, adequate iron intake and absorption are key to maintain optimal levels. Maintaining iron stores through diet alone can pose a significant challenge due to low bioavailability of haem (15-35%) and non-haem (2-20%) dietary iron, dietary restrictions (vegetarian/vegan), low energy intake, lack of knowledge and the post-exercise hepcidin response. In the hours (3-6h) following exercise, hepcidin levels increase 2-7-fold and absorption of dietary iron is suppressed during this window (McCormick et al., 2020). Findings have shown that morning hepcidin levels and those immediately after exercise (within 30 mins) are significantly lower, thus providing an effective period for consumption of iron-rich foods or supplements (McCormick et al., 2020). In addition, the female hormone oestrogen can influence iron metabolism via the suppressive effects on hepcidin, which when elevated, further reduces absorption of dietary iron (Hou et al., 2012). To the authors knowledge there is currently no research specifically looking at the effects of the primary female hormones' oestrogen and progesterone (and their synthetic form oestradiol and progestogens) in elite female football players.

If a player has ID, one strategy to resolve this is supplemental oral iron. Slow-release ferrous sulphate is the best tolerated form of supplementation, although it is important to note that this still causes a high incidence of gastrointestinal (GI) disturbances (Tolkien et al., 2015). A dose of ~100mg per day have proven to increase ferritin stores over an 8–12-week time frame (Sim et al., 2019). However, for players that suffer with GI issues alternate day supplementation has been proven to have a greater cumulative response (Sim et al., 2019). These regimes in combination with iron absorption enhancers such as vitamin C should be considered when devising an individual supplement strategy for a player.

PROBIOTICS

Probiotics are live microorganisms which, when provided in sufficient quantities have been shown to offer a multitude of health benefits such as gastro-intestinal (GI) health and immune health (Jäger et al., 2019). Current literature suggests that athlete populations have varying gut microbiota compositions in comparison to sedentary individuals, and as such, may experience GI distress (e.g. vomiting, nausea, diarrhea, bloating, acid reflux) in response to exercise, particularly at high intensities and long durations (Mohr et al., 2020). Since approximately 70% of the immune system is located in the gut, creating a healthier gut environment is one of the key benefits of probiotic supplementation for promoting immune responses. This also helps athletes avoid digestive issues and ensures optimal absorption of macronutrients which are essential for performance and recovery (Jäger et al., 2019). Previous data from elite rugby union players demonstrates that 4-weeks of supplementation with a probiotic mix containing 3 strains at a dosage of 3×10^9 (3 billion) colony forming units significantly reduced the duration and number of GI and upper respiratory tract infections (URTI) compared with a placebo (Haywood et al., 2014).

Due to their busy and often demanding schedules, female football players will frequently find themselves in situations which may include travel, exposure to crowds and poor hygiene at training and competition venues, all of which can increase their exposure to pathogens, increasing the risk of illnesses such as URTIs. Illness risk is also higher during periods of increased training load, sleep disruption and changes in environmental conditions, all of which have a further immunosuppressive effect (Walsh et al., 2011). As such, a probiotic supplement containing both Lactobacillus and Bifidobacterium may be beneficial for promoting immune health during specific periods throughout the season where situations of this type arise, particularly during any foreign travel and throughout training in the winter months. It is suggested that a minimum intervention time of 14 days is required to impact the immune response, since it takes this time for probiotics to colonise on the GI tract (Jäger et al., 2019). In this regard, a variety of probiotic strains have been studied in athlete populations, and a multi-strain formula may reduce the duration of supplementation needed for adhesion and colonisation on the GI tract.

COLLAGEN

Musculoskeletal injuries are the most common injury type in athlete populations with the incidence of soft tissue injury reaching up to 60% in players from the EPL (Baar, 2017). This is of particular significance to female athlete populations whereby ACL injury is 4 to 6 times more likely compared with male athletes (Hewett et al., 2016). Collagen is a key component of musculoskeletal connective tissues (tendons, ligaments, cartilage and bone), the structure and function of which depends on the abundance of collagen in the extracellular matrix (Baar, 2017; Shaw et al., 2017). Since collagen protein makes up more than 80% of tendons and ligaments, research over the last decade has investigated the value of collagen supplementation in joint pain, injury rehabilitation and injury prevention for athletes. Indeed, a study in 97 athletes who had previously suffered with joint pain demonstrated that supplementation with collagen hydrolysate over a 24-week period significantly reduced joint pain both at rest and while running and changing direction (Clark et al., 2008). In addition, recent data demonstrates that when combined with loading on the joint, supplementation with 15g of vitamin C enriched gelatine (a product rich in collagen) 1-hour prior to intermittent activity significantly improved collagen synthesis in comparison to 5g or a placebo (Shaw et al., 2017).

In females specifically, it has been reported that the mechanical properties of ligaments are influenced by hormones, with a downregulation in collagen synthesis observed when concentrations of estrogen increase (Liu et al., 1997). This results in ligament laxity and a reduction in mechanical function due to decreases in enzymatic crosslinking of collagen in the joint (Lee et al., 2015). This in turn may weaken the ligament, thereby increasing the risk of joint injuries in female athlete populations during the pre-ovulatory phase of their menstrual cycles (Lee et al., 2015). Indeed, data demonstrates that changes in knee joint laxity during the menstrual cycle does have an impact on joint loading during movement (Park et al., 2009), which has potential to increase the risk of joint injury.

In an applied setting it is therefore suggested that female football players consume a collagen rich supplement (containing ~15g collagen with 50mg of vitamin C) in the hour prior to training (Shaw et al., 2017), particularly during the pre-ovulatory phase of their menstrual cycles to promote collagen synthesis and minimise joint injury risk.

CREATINE

Around 60-70% of creatine is stored in skeletal muscle as phosphocreatine. Creatine is available in the diet through consumption of dairy, red and white meat and fish. In football, creatine is of particular interest due to phosphocreatine stores significantly declining during match play. Thus, with creatine supplementation, repeated sprint performance during both short and prolonged intermittent exercise can be improved. In addition, creatine has been shown to increase post exercise muscle glycogen resynthesis (Robinson et al., 1999). Although studies specifically looking at female footballers are sparse and often carried out in sub-elite groups, there has been a consensus that creatine supplementation is beneficial. Female college footballers supplemented with creatine increased strength but not lean tissue during an off season period (Larson-Meyer et al., 2000). While Cox et al., 2002 found that creatine improved repeated sprints and agility tasks in a soccer simulated match play in Australian national team players. Finally, Ramírez-Campillo et al. (2016) discovered that creatine in conjunction with plyometric training enhanced adaptations in amateur female football players.

There is currently an increase in vegetarian and vegan athletes. Research has proven that due to a lack of creatine in their diet, supplementing vegetarian athlete's with creatine increased; lean tissue mass, type II fibre area, insulin-like growth factor-1, muscular strength, muscular endurance, and brain function (Kaviani et al., 2020).

Some research has linked creatine supplementation with negative side effects. However, a recent meta-analysis found that there are no adverse, renal or hepatic consequences of creatine supplementation in females (de Guingand et al., 2020). Weight gain is often seen as a side effect of creatine. Although de Guingand et al. (2020) report no significant change in body weight in females supplementing with creatine, at an individual level some participants did report a small weight increase, which for some players may be undesirable.

While the evidence for creatine supplementation in female football players is currently limited, there is a strong rationale for supplementation. It could be of particular use for, strength training, improving repeated sprints, muscle glycogen resynthesis and vegetarian/vegan players. It is recommended to use a loading regime of 20g/day for seven days followed by a maintenance dose of 5mg/kg/day. Alternatively, to reduce potential side effects of the loading phase, 5mg/kg/day can be supplemented, but it will take an additional two weeks to obtain similar benefits.

CAFFEINE:

Caffeine (1, 3, 7-trimethylxanthine) is one of the most commonly used supplements in football (Mielgo-Ayuso et al., 2019). It is usually consumed in the form of beverage (coffee, tea, soft drinks, energy drinks), but increasingly in more novel forms such as chewing gum, energy gels and tablets. Unfortunately, in the past 40 years only 13.2% of research investigating caffeine erogenicity involved female athletes (Salinero et al., 2019). Overall evidence indicates that caffeine has the capacity to improve soccer specific skills such as vertical jump height, repeated sprint ability, running distance and passing accuracy (Mielgo-Ayuso et al., 2019). Caffeine supplementation is complicated in females due to oestrogen and oral contraceptives affecting caffeine metabolism and prolonging the half-life of caffeine. To the authors knowledge only two studies have looked at elite female footballers. In female football players taking oral contraceptives Ali et al. (2016) discovered that caffeine supplementation increased eccentric strength and power. Lara et al. (2014) found that 3mg/kg of caffeine in an energy drink enhanced jump height, repeated sprint performance, total running distance, and the distance covered at high intensity and sprint velocity during a simulated game. Further research needs to be conducted in female football players looking at the impact of caffeine on performance at various points in the menstrual cycle and those using hormonal contraceptives.

Despite its benefits, caffeine supplementation can have several side effects including insomnia, increased anxiety and gastric irritation. The response to caffeine can depend on a variety of factors including habitual intake, dose and genetics (Ruiz-Moreno et al., 2020).

Ergogenic effects of caffeine are typically achieved at doses between 3-6mg/kg 45-60 minutes pre-exercise (Mielgo-Ayuso et al., 2019). Apart from caffeine gum, plasma caffeine levels peak 45-60 minutes after ingestion, therefore it is recommended to consume caffeine during the warmup period. Due to quicker absorption through the buccal mucosa, caffeine gum should be consumed just before kick-off. Players should be aware of the timing of caffeine supplementation and the potential impact it can have on sleep. It is heavily advised that any supplementation is individualised to the player and practiced in training before being used on match day.

NITRATE

Dietary nitrate has become a popular topic in sport due to the impact of nitric oxide (NO) on a variety of physiological functions that are important during exercise. Inorganic dietary nitrate occurs naturally in foods such as beetroot, rocket and spinach, however athletes have started to supplement with concentrated nitrate shots, for convenience and proven performance benefits. Dietary nitrate is converted to NO via 2 pathways outlined in figure 2 (Jones, 2014).

Acute (2.5h prior to exercise) and chronic (3-15 days) nitrate supplementation with approximately 5-8mmol of nitrate, has shown to be beneficial to sub-maximal and high intensity exercise performance in trained, sub-elite athletes. Nitrate supplementation has more recently demonstrated an ergogenic purpose within high-intensity intermittent (HIIT) exercise, due to the dominance of the oxygen independent pathway which is enhanced under hypoxic conditions (Wylie et al., 2016). In recreational, male team-sport players, 5-days of nitrate supplementation (6-8 mmol) improved repeated sprint performance and reaction time (Thompson et al., 2016; Wylie et al., 2016). The underlying mechanisms optimising HIIT performance, similar to that of a competitive football match, include a reduction in the PCr cost of muscle force production, improved calcium handling, mitochondrial efficiency and type II muscle fibre function (Jones, 2014; Wylie et al., 2016). Unfortunately, both elite and female populations are under-represented in this area of research.

In healthy female adults, baseline levels of nitrite and nitrate were found to be higher compared to adult males (Kapil et al., 2010), suggesting that nitrate supplementation may have a blunted effect on performance in females. However, when correcting the doses relative to body mass, there were no significant differences. It has also been noted that female adults have a significantly greater dietary nitrate intake than men, which could be responsible for elevated levels of nitrite and nitrate at baseline (Jonvik et al., 2016).

In elite athletes it has been suggested that the advanced physiological adaptations that occur in response to chronic training, render them less responsive to the ergogenic effects of nitrate (Jones et al., 2018). Prolonged supplementation with high doses of nitrate has shown to have more promising effects on performance in highly trained athletes compared to acute, low doses (Jones et al., 2018). Additionally, the ergogenic effect of nitrate supplementation in elite athletes may vary depending on the mode of exercise used; high doses of nitrate (8.5 - 9.6mmol) have proven effective at optimising time trial performance in highly trained male rowers (Hoon et al., 2014) and elite female kayakers (Peeling et al., 2015). Researchers alluded to the potential for nitrate supplementation to have greater performance benefits in elite athletes with a higher proportion of type II muscle fibres (Jones et al., 2018). Further studies exclusively using female athlete population are required, however current findings suggest that ergogenic effects of nitrate supplementation are not exclusive to male athletes and may be enhanced in highly trained athletes whom have a greater proportion of type II muscle fibres.

Although the effects of nitrate supplementation may be blunted in an elite population, there is positive evidence to suggest that prolonged supplementation periods and/or acute high doses (8-10mmol) of nitrate may improve performance in elite female athletes competing in high intensity exercise events.

BETA ALANINE

Beta-alanine (BA) combines with L-histidine in the muscle to form β-alanyl-L-histidine (carnosine). Previous research has highlighted carnosine of particular interest given that it can act as an intracellular buffer to H^+. When comparing baseline intramuscular carnosine levels, females have between 12-72% lower levels compared to males. In addition, females often require lower levels of BA supplementation to obtain similar relative increases in carnosine compared to males (Stegen et al., 2014). BA supplementation can delay the onset of muscular fatigue and improve recovery during repeated bouts of high intensity exercise (Saunders et al., 2017). In females, BA supplementation has been show to increase time to exhaustion and decrease feelings of perceived exertion (Glenn et al., 2015). Given the repeated sprint nature of football, it has become increasingly common practice for football players to supplement with BA. Unfortunately, the effects of BA on football specific protocols are unclear and contradictory. In international youth female footballers, BA supplementation did not attenuate a drop in exercise intensity over an intense period of training (Ribeiro et al., 2020). Previous research in elite female soccer players found that a combination of BA and plyometric training compared to plyometric training alone did improve a running aerobic sprint test (Rosas et al., 2017). A potential side effect of supplementing with BA is paraesthesia, although harmless, can cause some discomfort to the athletes.

The evidence in female football players is inconclusive but there is a strong scientific rationale to supplement with BA. Based on current research female football players should use a loading dose for 4 weeks and a maintenance dose based off their weight (Stegen et al., 2014). It is recommended that players weighing 56kg dose with $2.5g \cdot d^{-1}$, 64kg with $3.4g \cdot d^{-1}$ and heavier (>70kg) $5.5g \cdot d^{-1}$. A maintenance dose of $18mg \cdot kg^{-1}$ BW per day is recommended due to the correlation between weight and maintaining muscle carnosine levels (Stegen et al., 2014). To help limit the chance of the player suffering with paraesthesia, it is recommended that the dose is split into 0.8-1.6g every 3-4 hours.

SUMMARY

Over the past decade, there has been an increase in research specific to the female athlete. With the increasing popularity of supplement use in athlete populations, the current review provides an overview of some of the key supplements with evidence to suggest they may have benefit in promoting the health, recovery, and performance of female football players. A guide to their practical applications in the sport throughout the season is also included. When choosing a supplement, both players and practitioners are advised to use the SENr supplement decision making flowchart to choose safe batch tested products with scientific evidence to support their use.

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Figure 1. Supplement decision making flow chart.

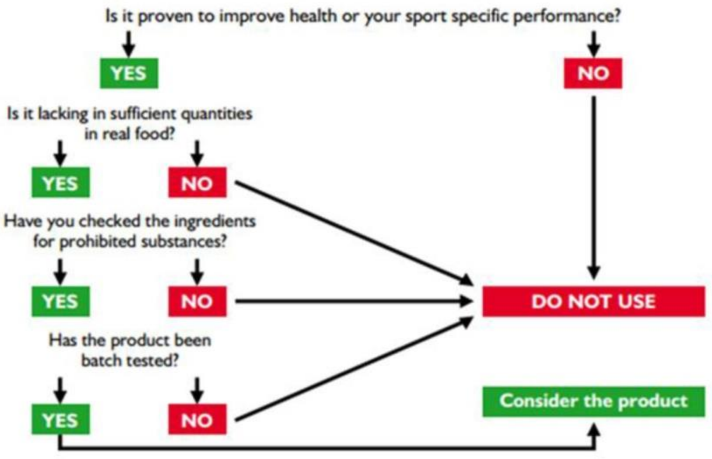

Figure 2. Pathways and physiological benefits of nitric oxide production

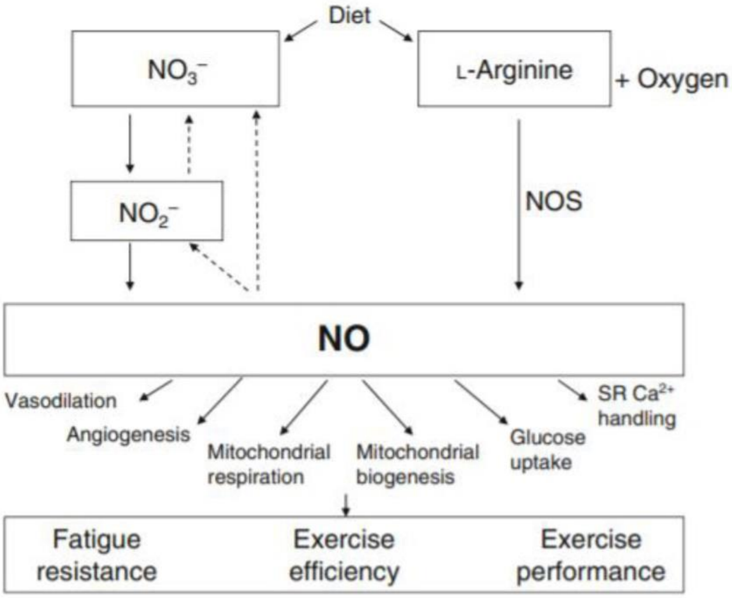

Table 1. National Academy of Medicine (NAM) guidelines for the classification of Vitamin D status (adapted from Owens *et al.*, 2018).

25[OH]D concentration (nmol.L^{-1})	Classification
<12	Severely deficient
12-<30	Deficient
30-50	Inadequate
>50	Adequate
>75	Adequate for athletes (Owens et al., 2017)
>180	Toxic